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WATER RESOURCES ACTIVITIES IN THE UNITED STATES. WATER FACTS AND PROBLEMS

Luna Leopold

Select Committee on National Water Resources, U. S. Senate

August 1959

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86th Congress
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WATER RESOURCES ACTIVITIES
IN THE
UNITED STATES

SELECT COMMITTEE ON NATIONAL WATER RESOURCES
UNITED STATES SENATE

PURSUANT TO

S. Res. 48

EIGHTY-SIXTH CONGRESS
FIRST SESSION

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FOREWORD

AUGUST 18, 1959.

Under the provisions of Senate Resolution 48, of the 86th Congress, the Select Committee on National Water Resources is charged with making exhaustive studies of the extent to which water resources activities in the United States are related to the national interest and of the extent and character of water resource activities, both governmental and nongovernmental, that can be expected to be required to provide the quantity and quality of water needed for use by the country's population, agriculture, and industry, between the present time and 1980, with suitable provisions for related recreational, and fish and wildlife values. Among other things, the committee will be concerned with the ability of the Nation's water resources to sustain the continued economic growth which is necessary if our country is to remain strong and to enjoy an ever-increasing standard of living.

From time to time present demands on our water supplies are of such magnitude that critical situations have developed, and as demands increase it is evident that areas of deficient supplies will expand unless remedial measures are taken. The committee will be concerned with steps which will need to be taken now and in the future to lessen present problems and to reduce areas of prospective deficiencies.

As a part of the background for the committee's deliberations, I invited Dr. Luna Leopold, chief hydraulic engineer of the U.S. Geological Survey, Department of the Interior, to appear before the committee to discuss the Nation's water resources and the problems connected with their utilization.

Dr. Leopold's presentation was based on the experience of the Geological Survey obtained over the years, during which it has been concerned with water resources. The charts from which Dr. Leopold spoke and the brief narrative statements which he prepared to go along with them, present a broad general picture of water use and problems in the United States.

It is my belief that the charts and graphs presented by Dr. Leopold, together with the brief descriptive comments thereon, will be helpful to all Members of the Senate and to others interested in finding solutions to the Nation's water resources problems. Accordingly, I am having them printed as the first of a series of committee prints dealing with the various aspects of water resources activities which will be considered by the committee.

ROBERT S. KERR,
Chairman, Select Committee on National Water Resources.

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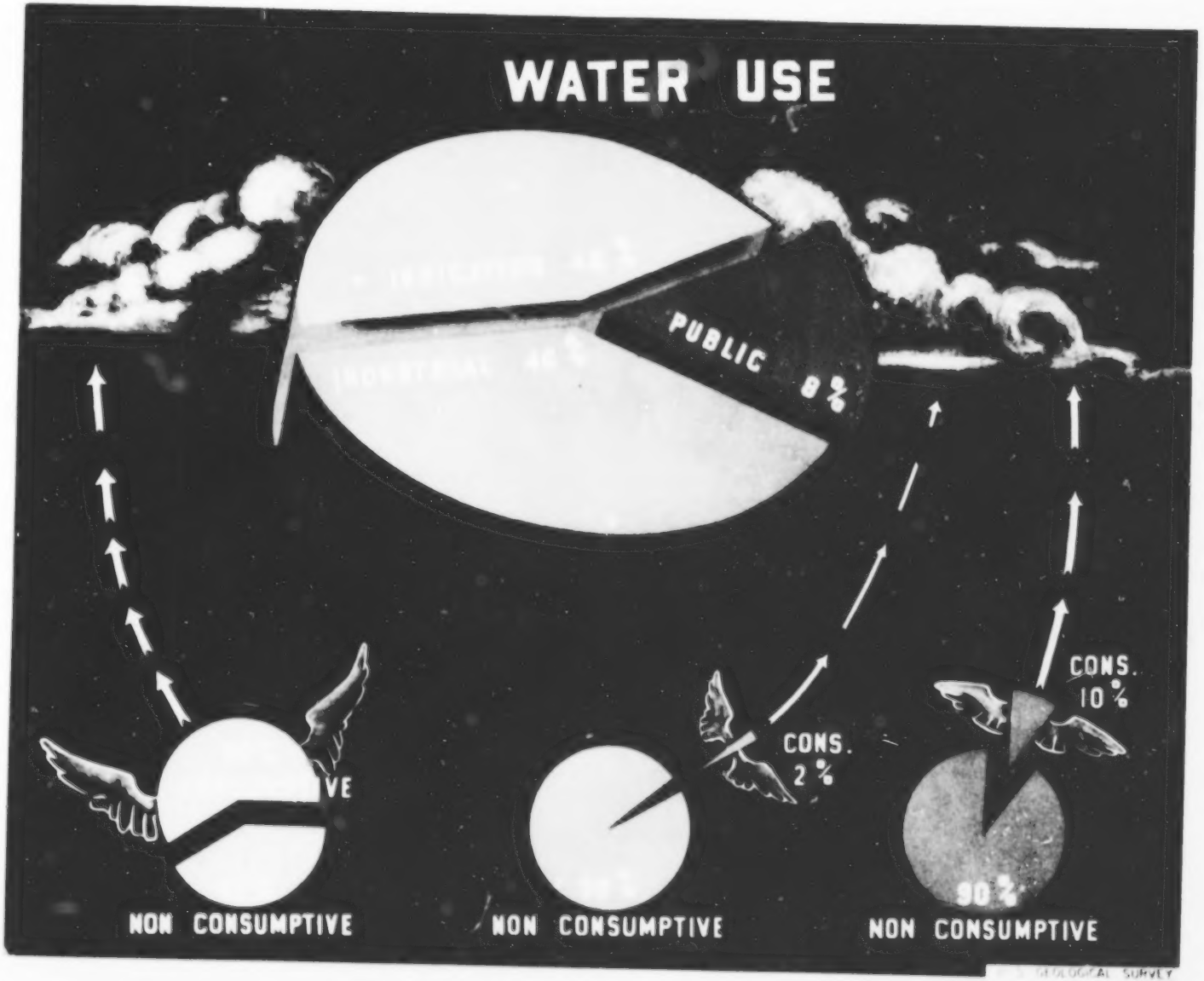
OUR WATER SUPPLY
ATMOSPHERE
PRECIPITATION
30"
EVAPO-
TRANSPIRATION
1
2
FLOW INTO OCEAN

Our water supply comes from rain and snow. If the total quantity that falls on the United States in an average year were spread evenly over the country it would stand 30 inches deep. Some of this water returns to the atmosphere, some seeps into the ground, and some runs off through stream channels. Not all of the 21 inches returning to the atmosphere is waste—a part of it supports cultivated crops, forests, and native grass. The 9 inches draining from land surface and ground-water seepage is the manageable supply. From it we now withdraw 3 inches, of which 1 inch returns to the atmosphere and 2 inches return to the stream network.

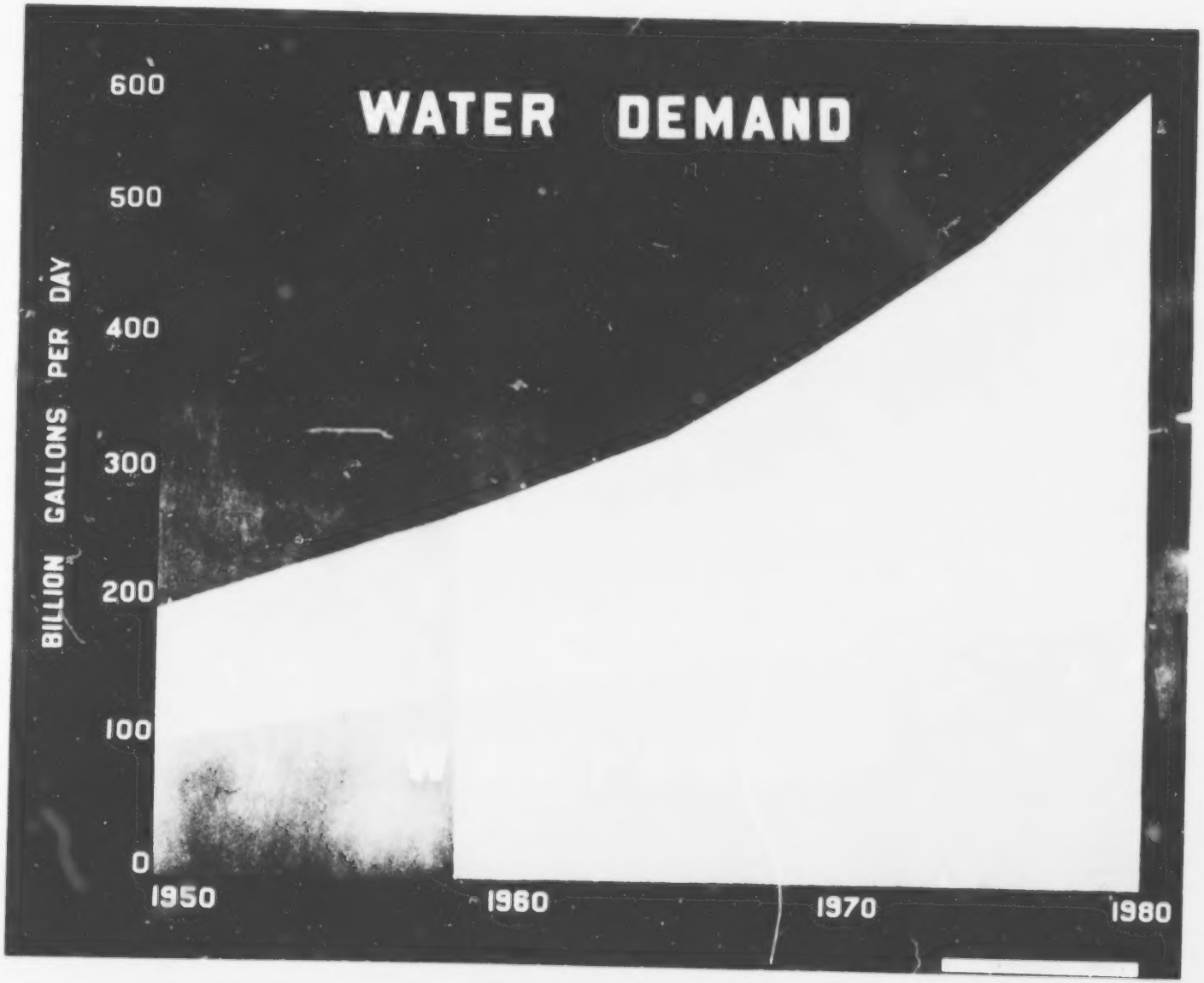
WITHDRAWALS
LAKES AND STREAMS
FRESH
WELLS
SALINE

44931 O - 60 - 2

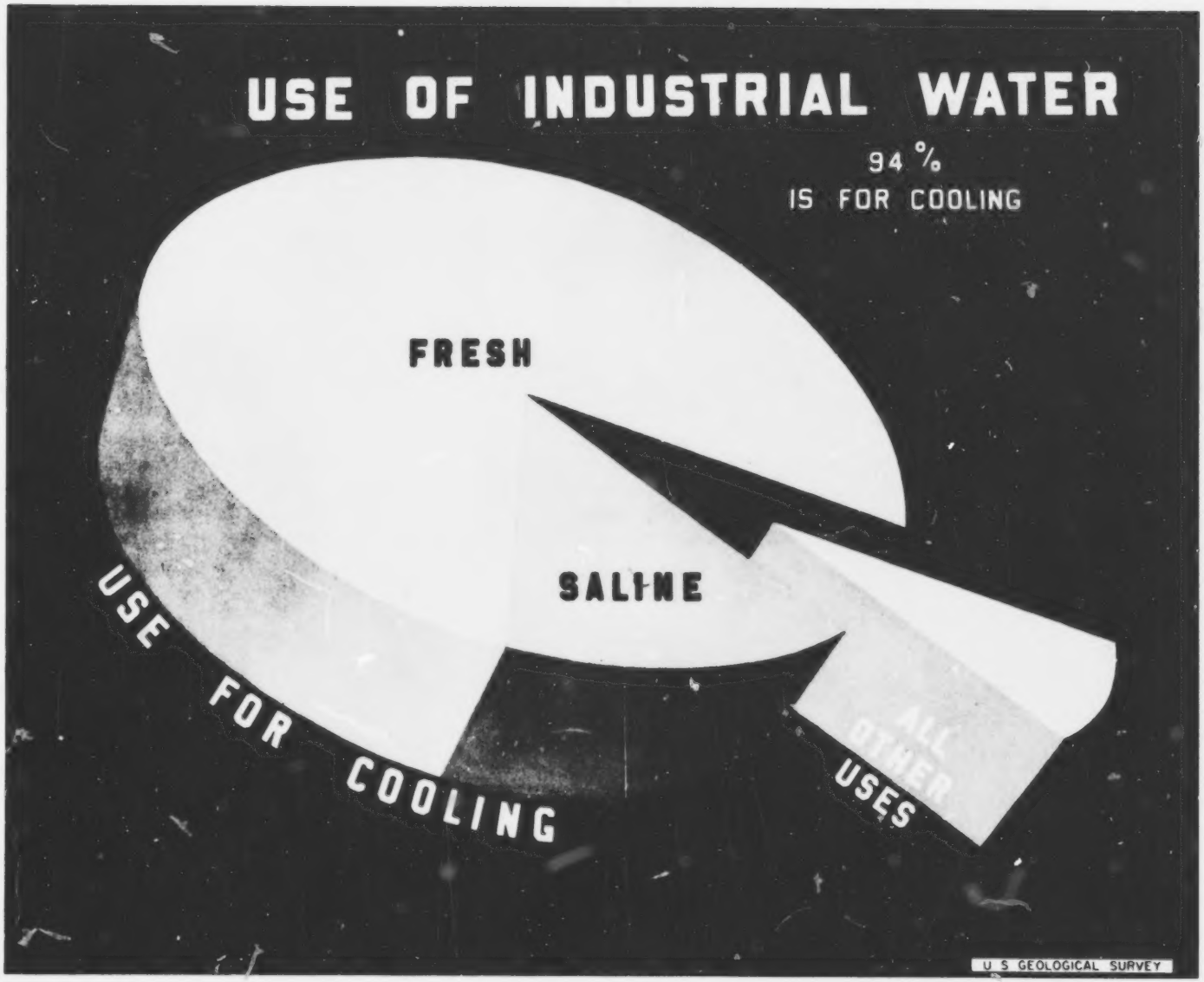
Of the 3 inches of water withdrawn for use, 80 percent is from lakes and streams and the remaining 20 percent is from wells. Some users can tolerate water having a high salt content, more than 1½ tons of salt per acre-foot of water. About 8 percent of the water withdrawn has a high salt content; most of this water is withdrawn from the tidal reaches of streams.


WATER USE
PUBLIC 8%
CONS.
2%
CONS.
10%
90%
NON CONSUMPTIVE
NON CONSUMPTIVE
NON CONSUMPTIVE

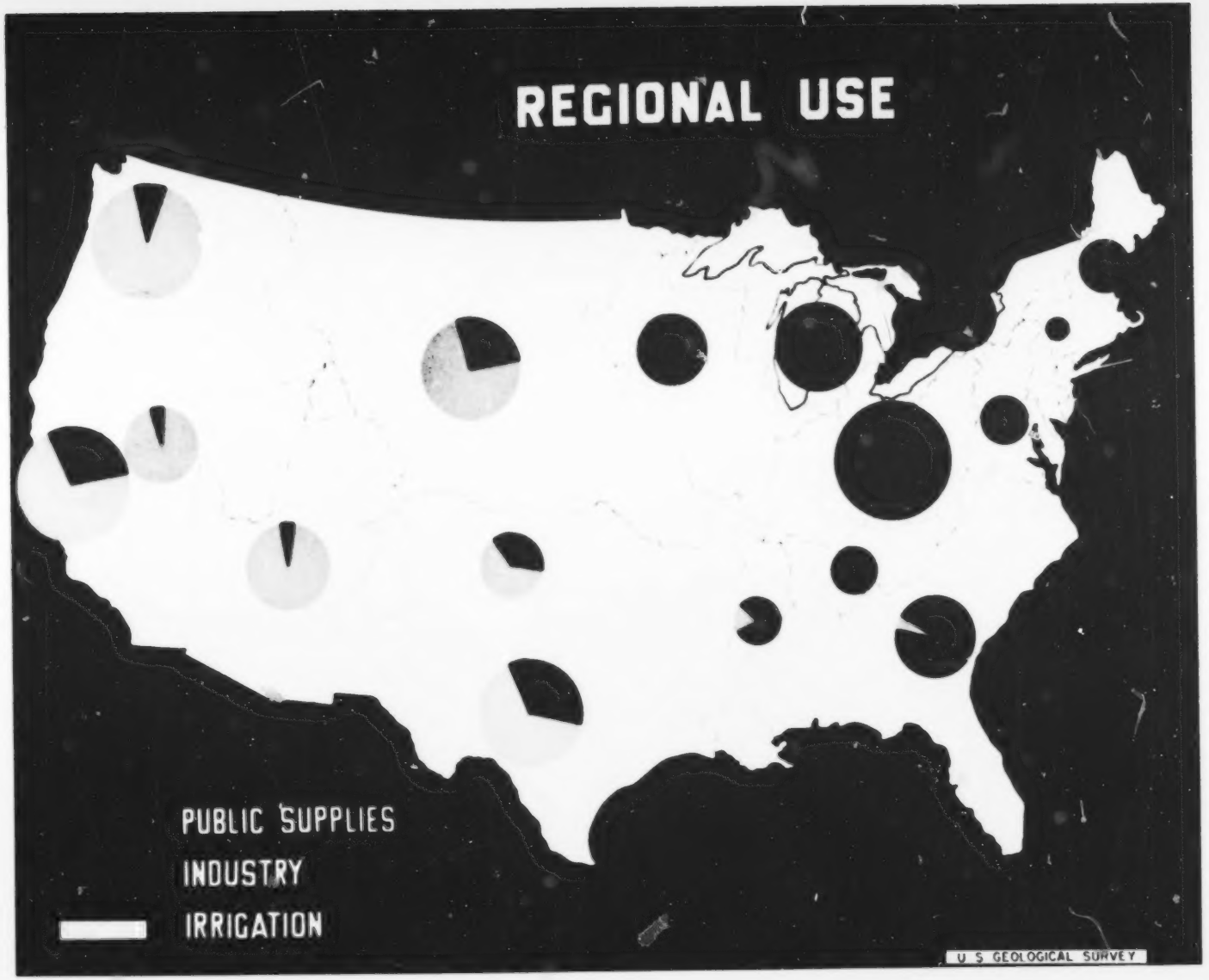
The amount of water consumed is one of the most important characteristics of water use. Water that is evaporated or is incorporated in a product is consumed. Irrigation accounts for 80 to 90 percent of all water consumed.


WATER DEMAND
BILLION GALLONS PER DAY
600
500
400
300
200
100
0
1950
1960
1970
1980

At present we use about 270 billion gallons per day. Demands will increase until by 1980 we will be using almost 600 billion gallons per day. The increase in the 31 Eastern States will be almost 200 percent but only about 50 percent in the Western States. This regional difference is significant because use in the Western States is predominantly irrigational, whereas in the Eastern States it is predominantly industrial. Therefore, the greatest increase will be in nonconsumptive use.

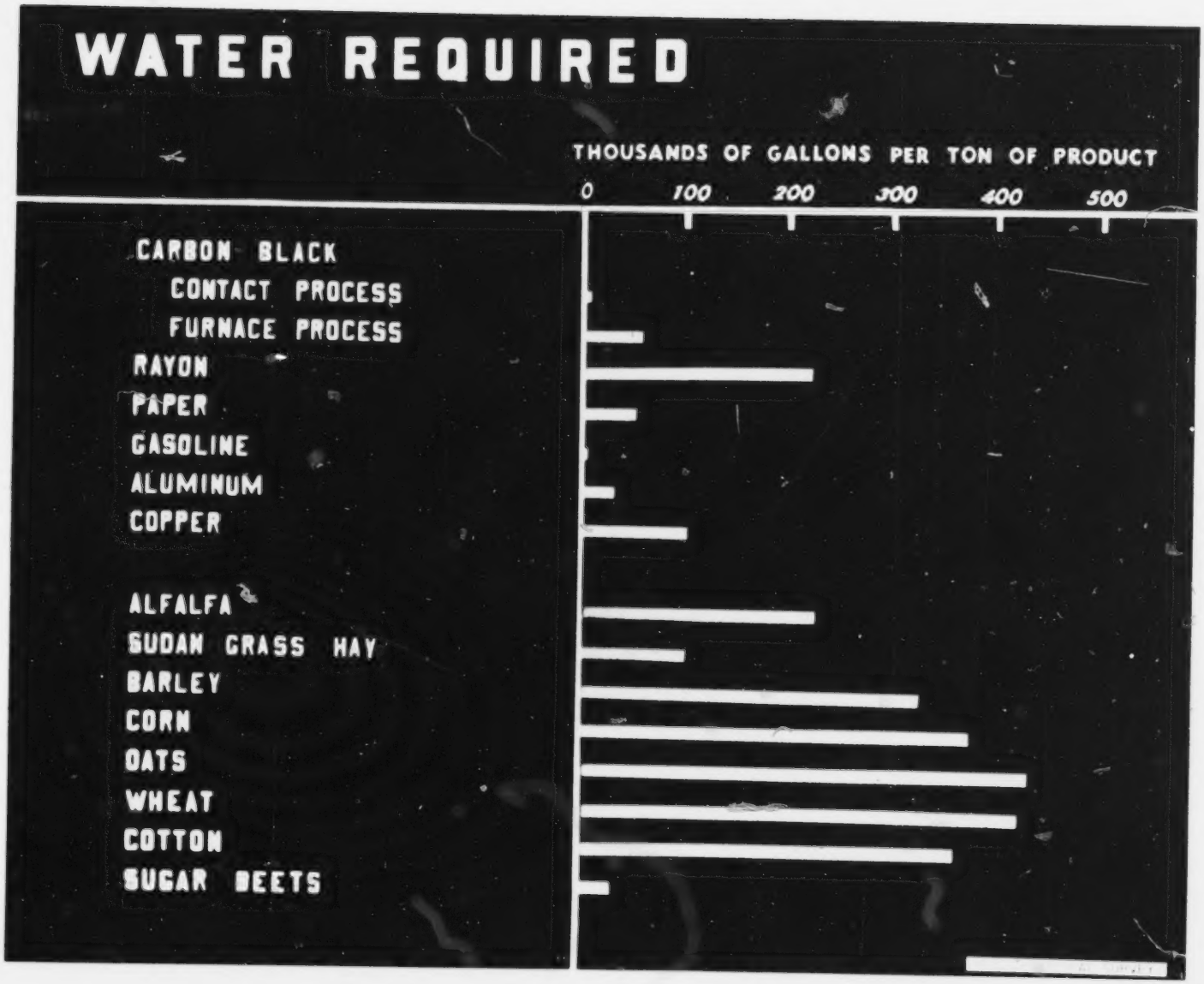

USE OF INDUSTRIAL WATER
94 %
IS FOR COOLING
FRESH
SALINE
USE FOR COOLING
ALL OTHER USES
U S GEOLOGICAL SURVEY

Ninety-four percent of all industrial water is used for cooling and seventeen percent of the cooling water is saline. Saline water and other water of poor quality can be used for cooling if the machinery is designed to use such water. If necessary, much more saline water could be used, especially in coastal areas, thus releasing water of good quality for other uses.

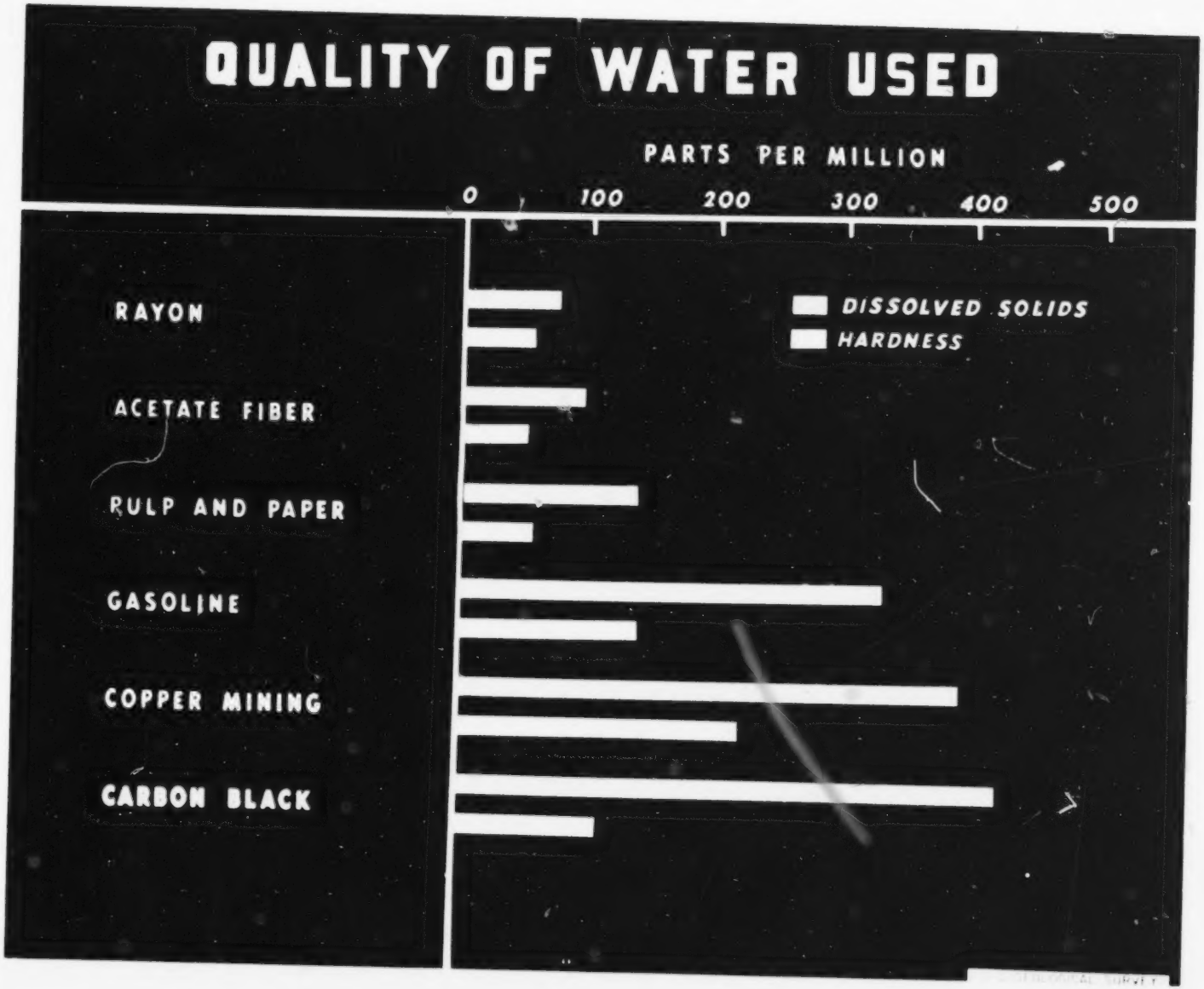

REGIONAL USE
PUBLIC SUPPLIES
INDUSTRY
IRRIGATION
U. S. GEOLOGICAL SURVEY

The record of water use by regions in the United States reflects the economy of the Nation. Agriculture in the West depends on adequate water for irrigation, whereas industry is concentrated in the East partly because of plentiful water. The small return flows from irrigation intensify the water problems of the West by depleting both the quantity and the quality of water supplies.

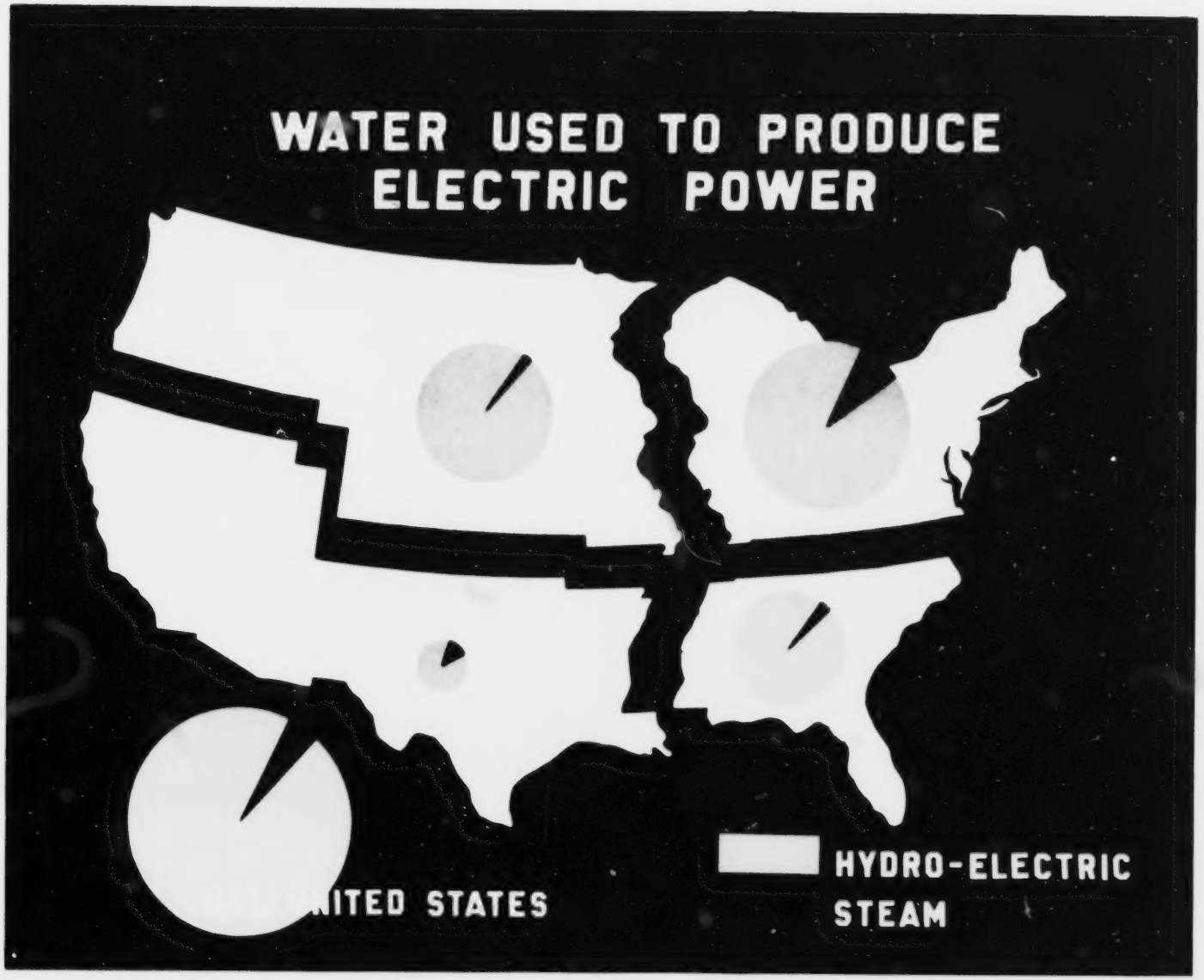
44933 O—59——3


WATER REQUIRED
THOUSANDS OF GALLONS PER TON OF PRODUCT
0
100
200
300
400
500
CARBON BLACK
CONTACT PROCESS
FURNACE PROCESS
RAYON
PAPER
GASOLINE
ALUMINUM
COPPER
ALFALFA
SUDAN GRASS HAY
BARLEY
CORN
OATS
WHEAT
COTTON
SUGAR BEETS

The amount of water required per ton of product ranges widely. Industrial products, however, usually require less water than agricultural products. Furthermore, industrial processes are usually less consumptive than agricultural processes. Industry therefore reduces the water supply less than agriculture. To evaluate the effectiveness of water used for different purposes, one must consider the contribution of the individual product to the national economy.


QUALITY OF WATER USED
PARTS PER MILLION
0
100
200
300
400
500
DISSOLVED SOLIDS
HARDNESS
RAYON
ACETATE FIBER
RULP AND PAPER
GASOLINE
COPPER MINING
CARBON BLACK

The water quality tolerated by industry ranges widely and depends on how the water is used. These tolerances take many forms and include a large variety of quality characteristics—dissolved solids and hardness are but two of them. Water used for some cooling processes can be of rather poor quality; but water for most processes wherein it enters or contacts the product must be of good quality. Rayon is an example of an industry which requires a soft water, low in dissolved solids. Iron and manganese in the water stain the rayon fiber and may affect bleaching and dyeing.

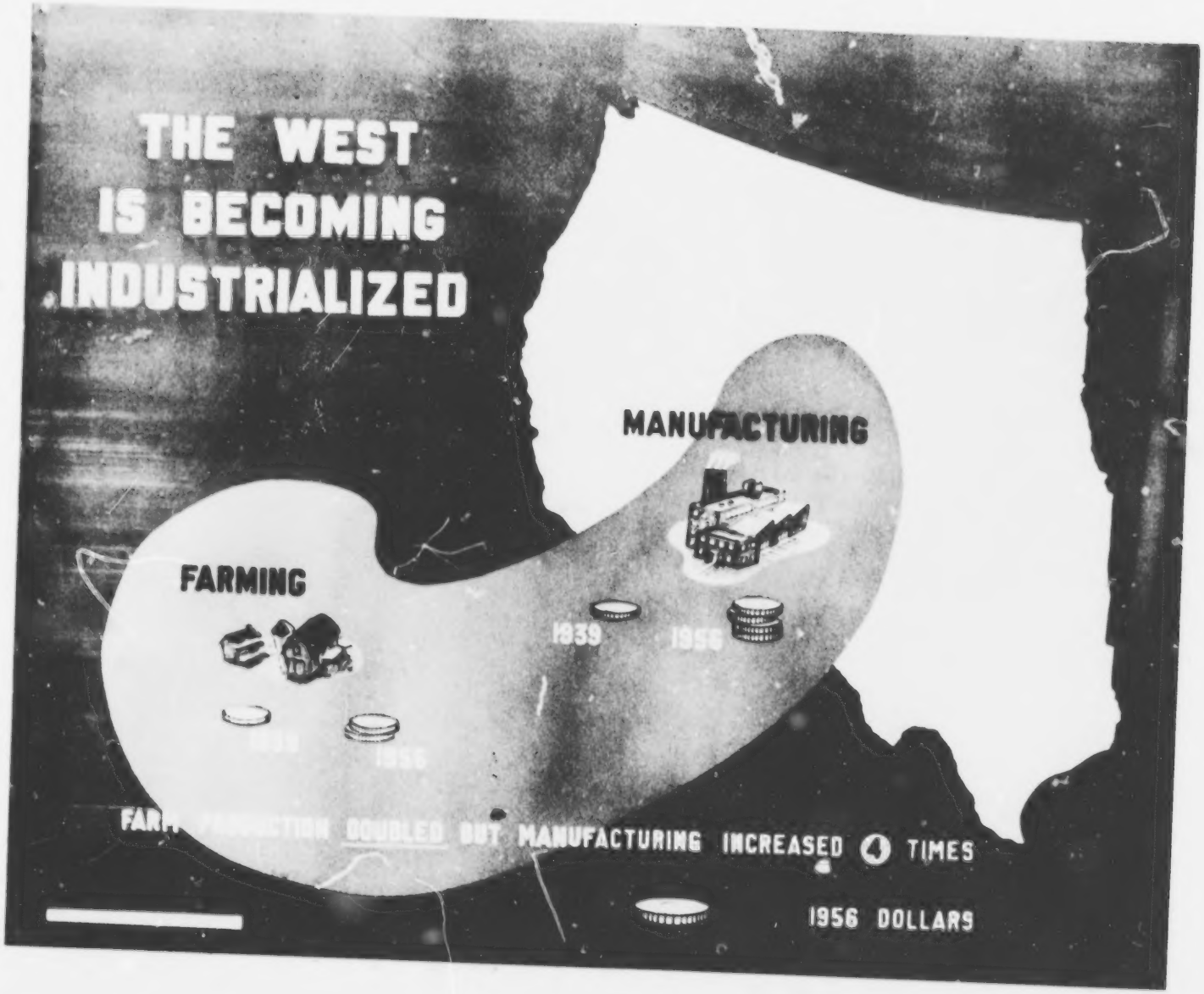

WATER USED TO PRODUCE
ELECTRIC POWER
ITED STATES
HYDRO-ELECTRIC
STEAM

Although more electric power is developed with steam than with hydropower, the latter requires more water. Except for temperature change, hydropower and generation of steam power have very little effect on the supply.

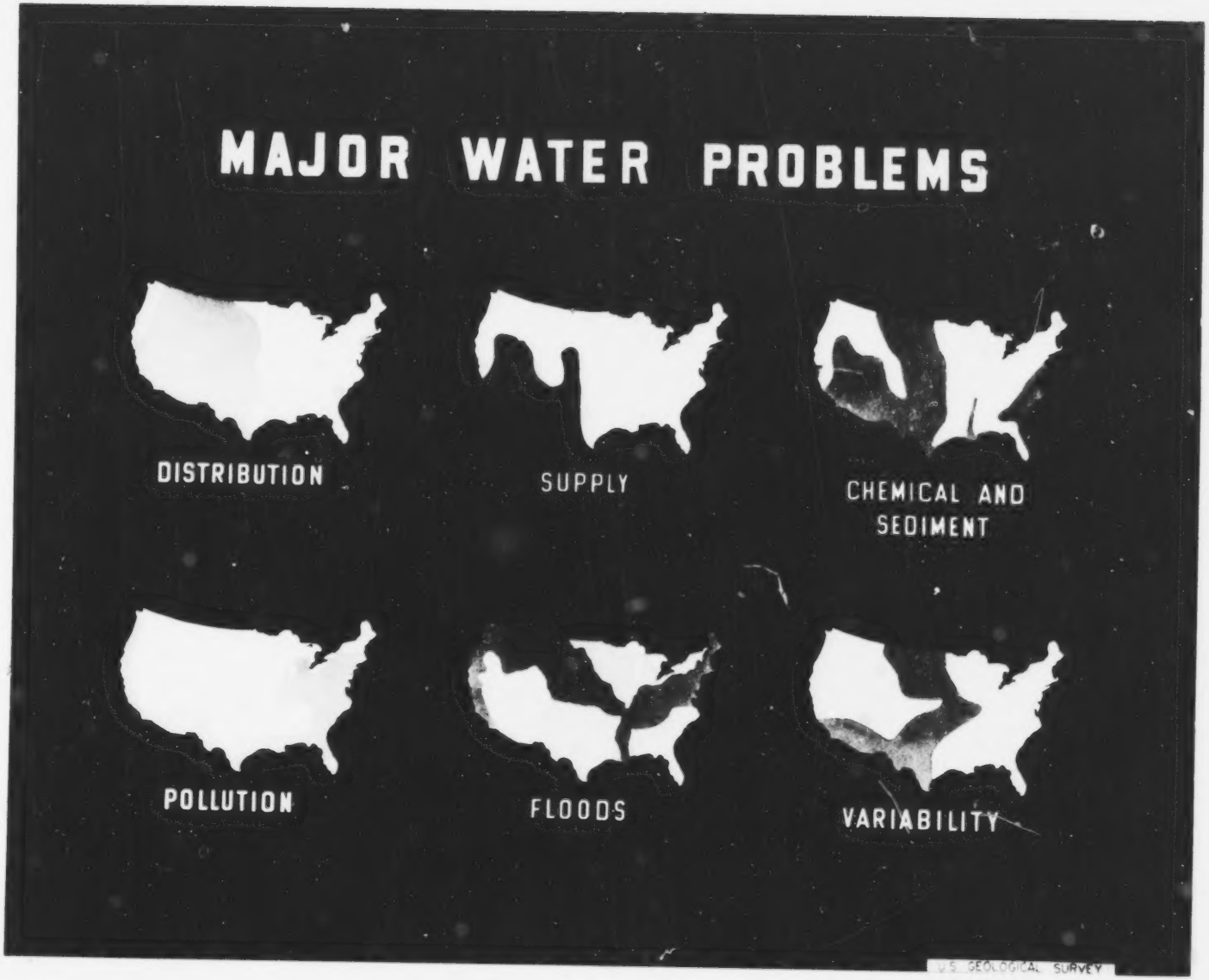
WELLS CAN DEPLETE STREAMS

44933 O—59——4

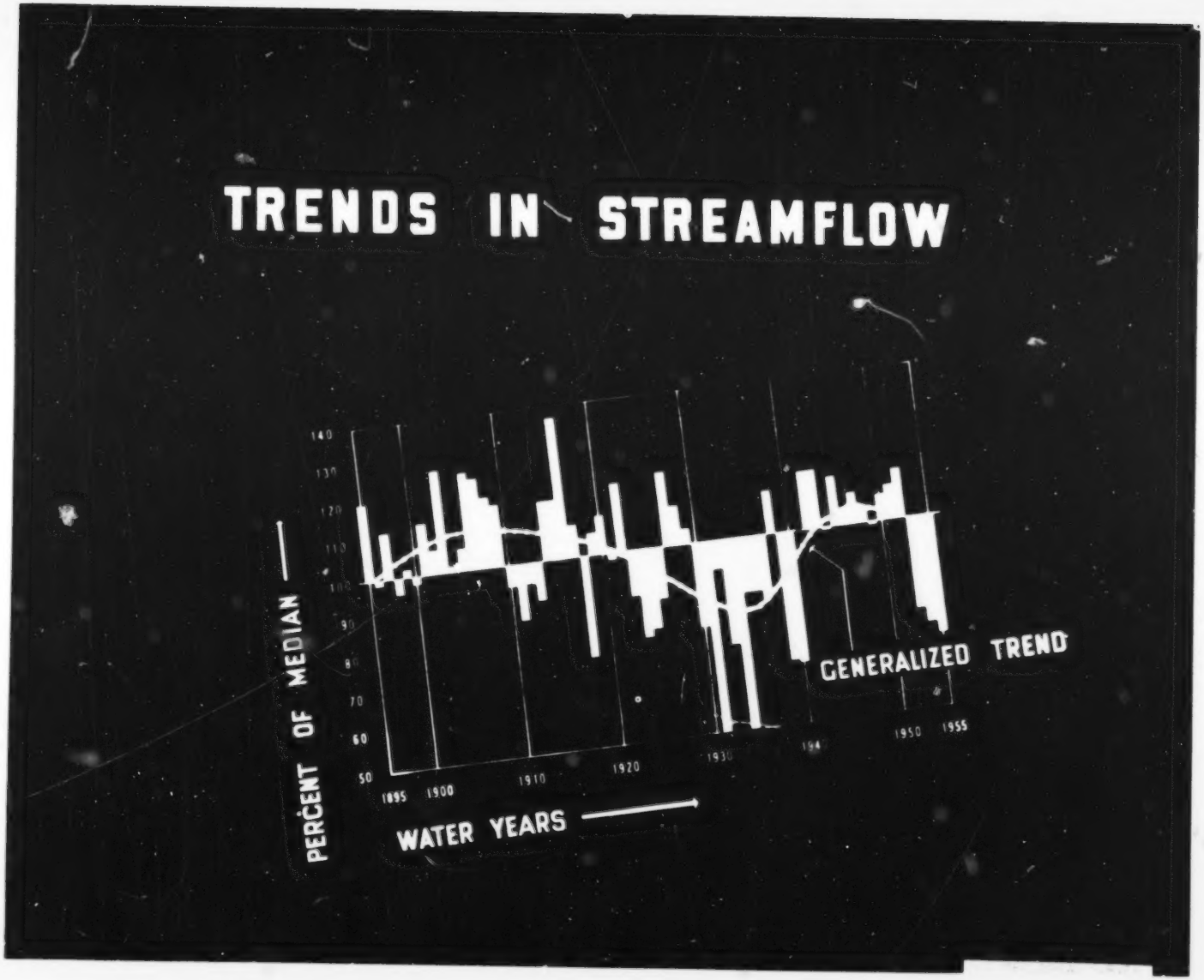
At many locations in the United States large wells constructed in river valleys are pumped for irrigation. Because the material underlying the topsoil in the valley is normally a coarse sand or gravel, it transmits water readily. When the large wells are pumped for many days river water moves through the valley deposits to the wells.


THE WEST
IS BECOMING
INDUSTRIALIZED
MANUFACTURING
FARMING
1939
1956
DOUBLED
BUT MANUFACTURING INCREASED 4 TIMES
1956 DOLLARS

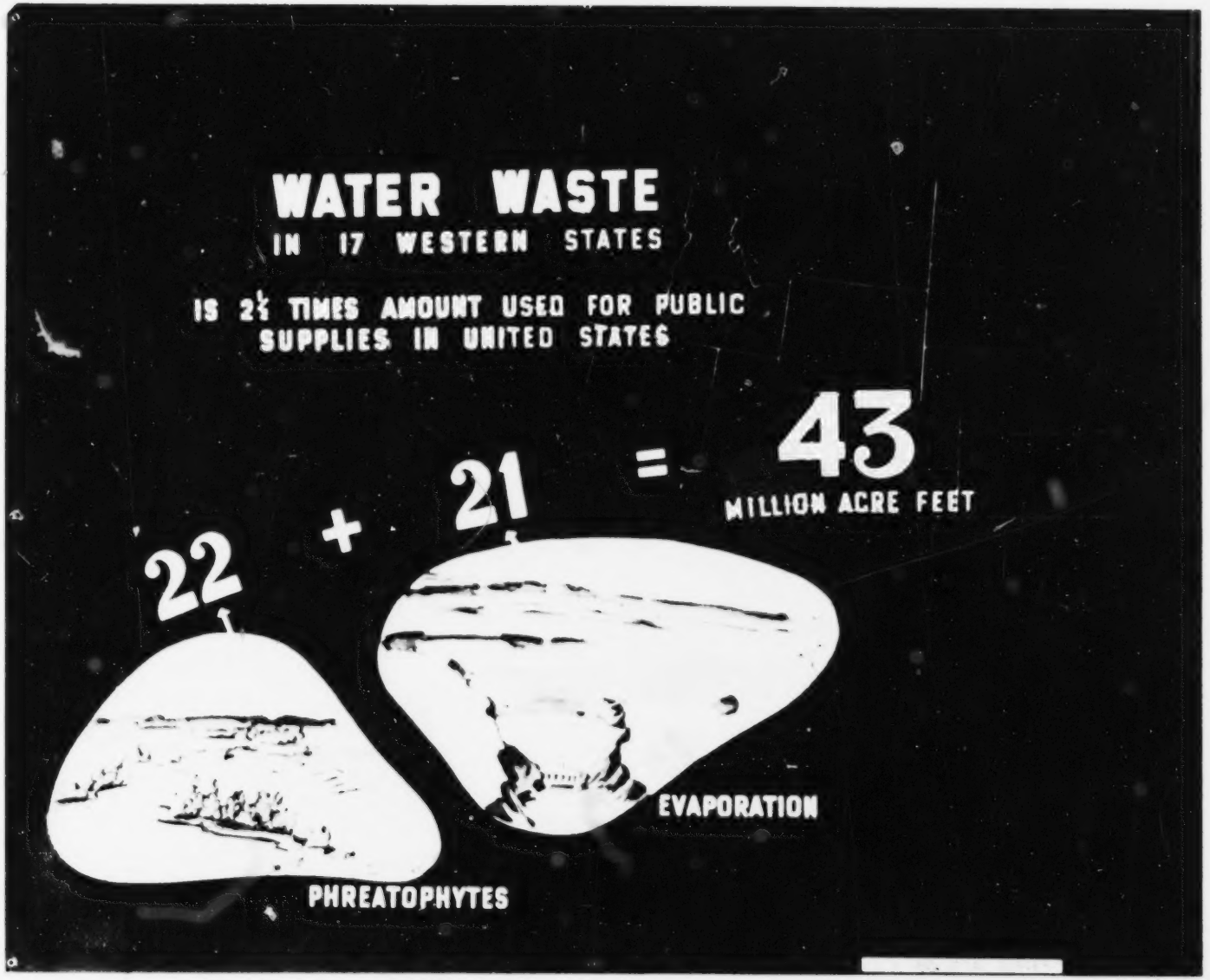
The economy of the West is turning to industry, which yields a higher dollar return than agriculture for the water used. From 1939 to 1956 manufacturing in the West increased at twice the rate of agriculture; whereas in the East they increased at the same rate. Of the industries moving to the West, those predominate which use small quantities of water per employee, such as electrical supply and fabricating industries.


MAJOR WATER PROBLEMS
DISTRIBUTION
SUPPLY
CHEMICAL AND SEDIMENT
POLLUTION
FLOODS
VARIABILITY
U.S. GEOLOGICAL SURVEY

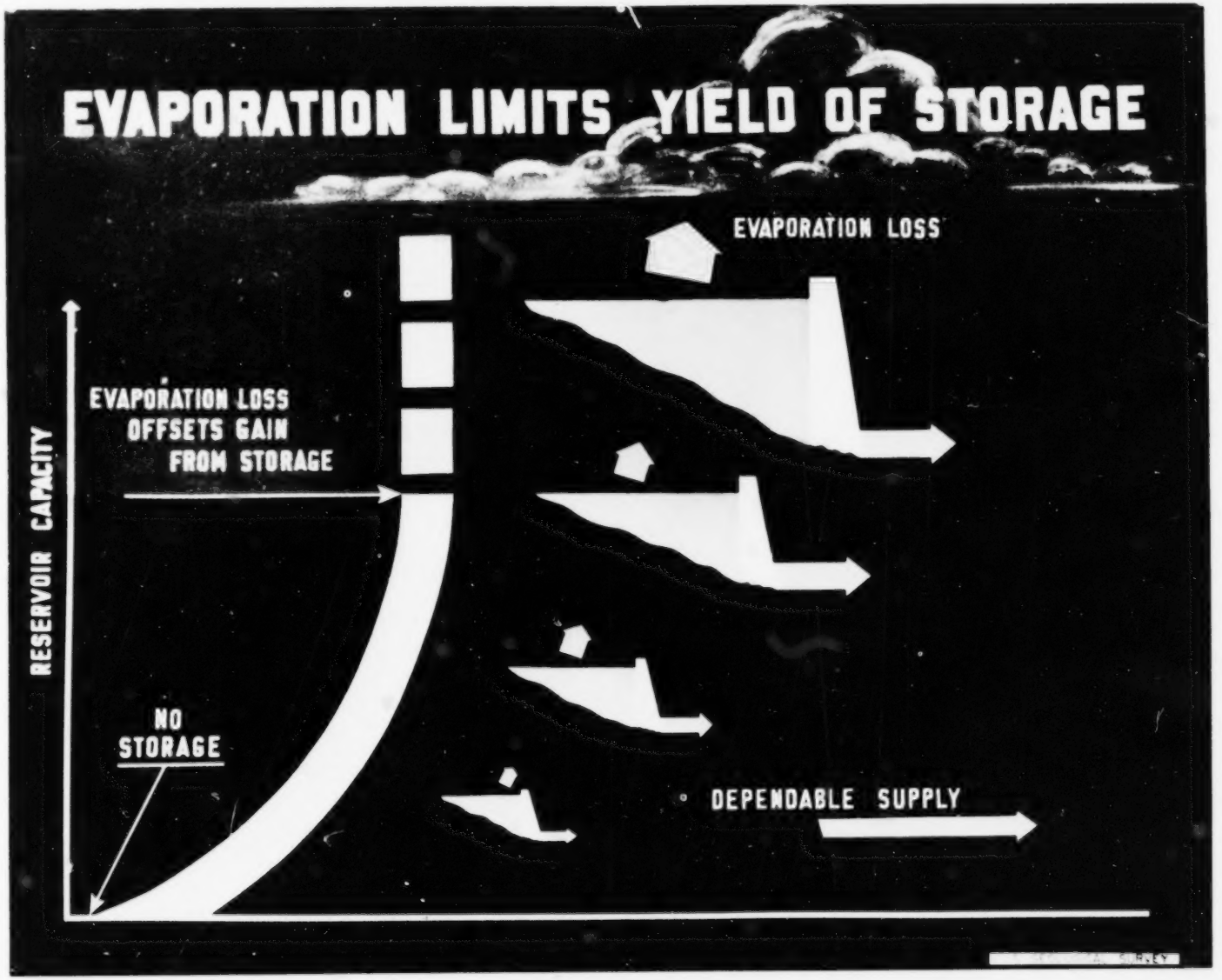
We have six major water problems; however, these problems do not commonly occur everywhere. The maps above show where those problems are most likely to occur. The water-supply situation is most critical in those areas where several of the problems exist. All six problems can be solved at a price. The six major problems then resolve into a single national problem, how to obtain ample water of high quality at a reasonable price.


TRENDS IN STREAMFLOW
PERCENT OF MEDIAN
140
130
120
110
100
90
80
70
60
50
1895
1900
1910
1920
1930
1940
1950
1955
WATER YEARS
GENERALIZED TREND

Continuous records of streamflow have been collected at key gaging stations of the United States since about 1890. These records show long-term trends in the variation in annual streamflow. The variability is almost entirely related to the variability of annual precipitation. We know that Western United States has experienced alternate periods, many years in length, of abundant moisture and drought. The generalized trend of streamflow was above normal from 1895 to 1922. The drought, 1930–40, was so severe that many water developments built during the years of good supply were without water. If the long-term variations in supply could be accurately forecast we would be able to schedule water use with increased reliability.


WATER WASTE
IN 17 WESTERN STATES
IS 2½ TIMES AMOUNT USED FOR PUBLIC SUPPLIES IN UNITED STATES
22 + 21 = 43
MILLION ACRE FEET
EVAPORATION
PHREATOPHYTES

Available supplies could be increased by reducing waste which occurs in the 17 Western States where evaporation rates from water surfaces are high because of strong winds and dry air. In these Western States considerable water is lost by evaporation from the surfaces of large storage reservoirs; for example, about 7 feet of water is evaporated annually from the surface of Lake Mead. Similar to the water lost by evaporation is that transpired by worthless water-loving vegetation that grows along streams and canals or in seeped areas. If half of the present water waste could be saved at least 5 million acres of land could be watered.


EVAPORATION LIMITS YIELD OF STORAGE
EVAPORATION LOSS
EVAPORATION LOSS
OFFSETS GAIN
FROM STORAGE
RESERVOIR CAPACITY
NO
STORAGE
DEPENDABLE SUPPLY

Dependable flow of a stream can be increased by storing high flows for release later when natural streamflow is low, but some of the water stored is lost by evaporation. The water surface and consequently the amount of evaporation increases as the amount of storage increases. On large reservoir systems in the Western States a point of diminishing return is reached at which loss of water by evaporation offsets gains in dependable flow.

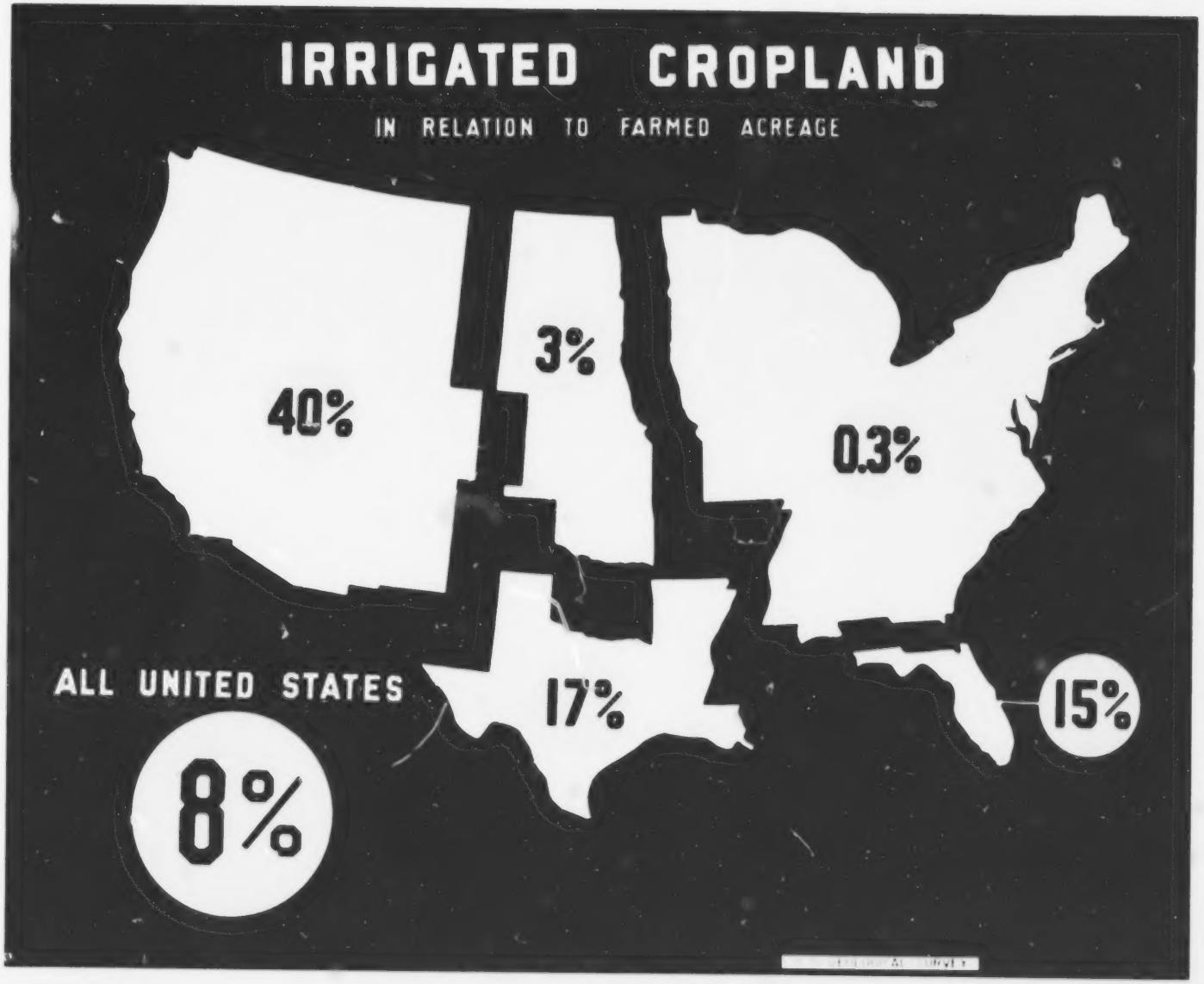
DIMINISHING RETURN FROM RESERVOIRS
RESERVOIR
RESERVOIR
NO STORAGE
YIELD 9MGD
STORAGE 8,800 MG
YIELD 35 MGD
STORAGE 37,000 MG
YIELD 70 MGD
COST PER MGD
$
$

The flow of a typical stream during the month of greatest flow is about 15 times the flow during the month of least flow. During about 9 months of the year the flow remains below average. The year-round dependable supply can be increased by storing water from high flows and releasing it to augment low flows.

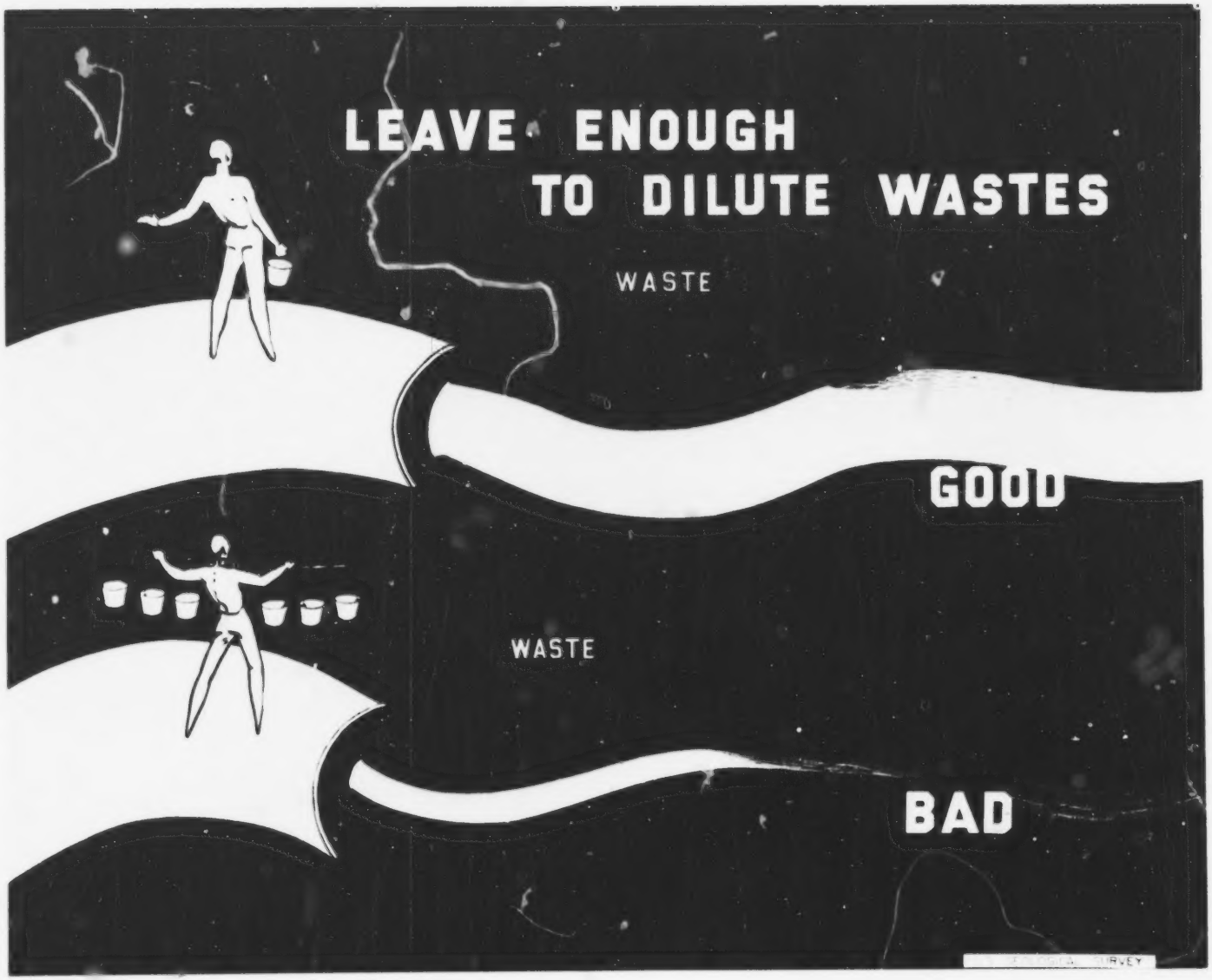
Each increase of dependable flow requires additional storage capacity, and the ratio of capacity to dependable flow increases as dependable flow is increased. In the example shown, the storage capacity had to be increased four times to double the dependable flow. The cost of increasing dependable flows beyond a certain value becomes prohibitive because of the high cost of storage.

MINING WATER
20"
0.2"
50,000 ACRE-FEET RECHARGE EACH YEAR
7,000,000 ACRE-FEET PUMPED OUT EACH YEAR
STORED WATER ALREADY USED
GROUND WATER RESERVOIR
200,000,000 ACRE-FEET
HIGH PLAINS

Mining water is pumping it from the ground at a faster rate than it is being replenished. In 1958, ground water was removed from a 25,000 square mile area in the high plains of Texas and New Mexico 140 times faster than it was being replenished. At the present rate the supply would be exhausted in 30 years; however, pumping rates and farm income will decrease as increasing depths to water make pumping more expensive and wells less productive.

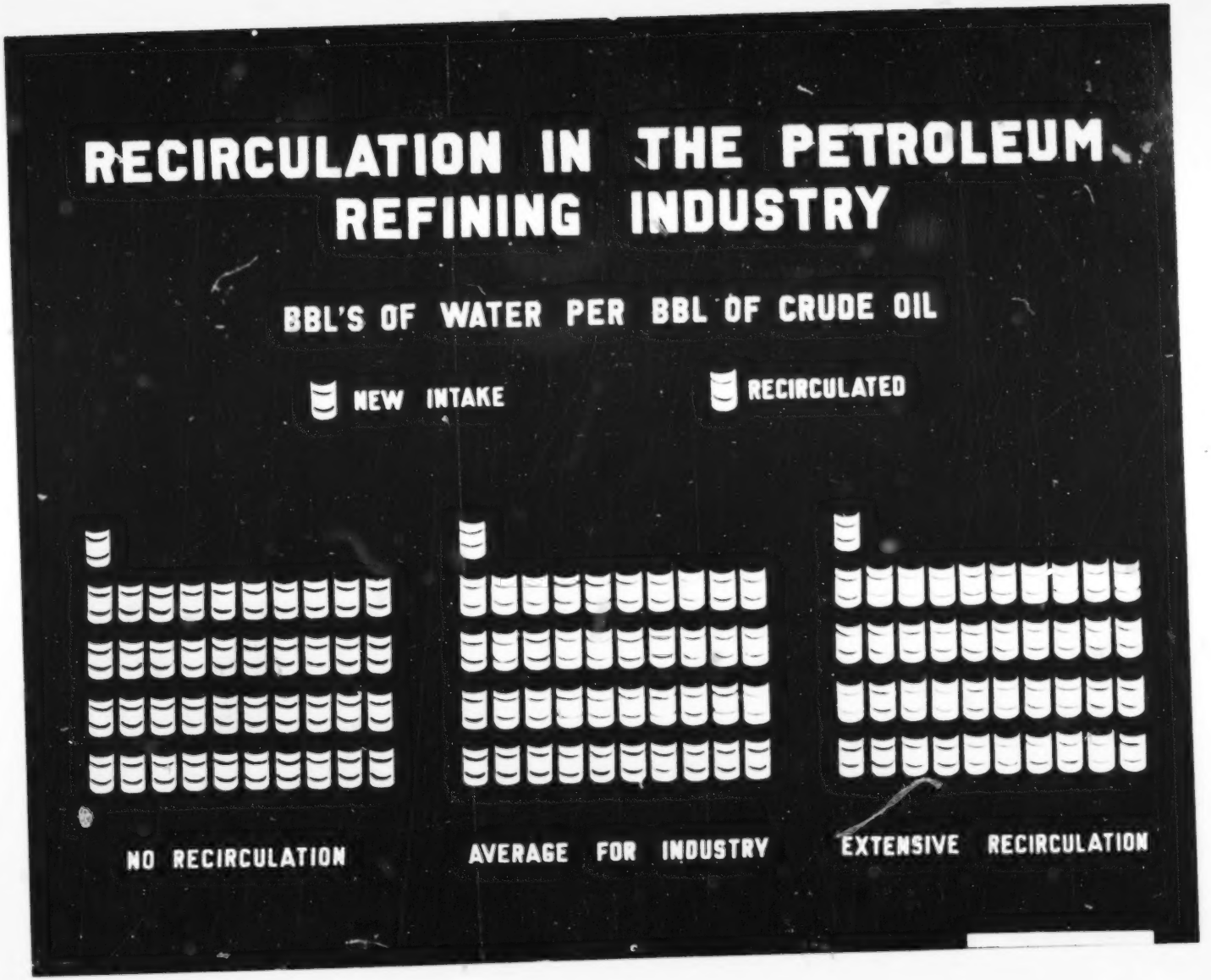

IRRIGATED CROPLAND
IN RELATION TO FARMED ACREAGE
40%
3%
0.3%
17%
15%
ALL UNITED STATES
8%

The need for irrigation water for crop production varies much over the United States. In many parts of the West no crops can be produced without irrigation. In the humid East crop production has been independent of irrigation, although recently supplemental irrigation has been used to increase yields.

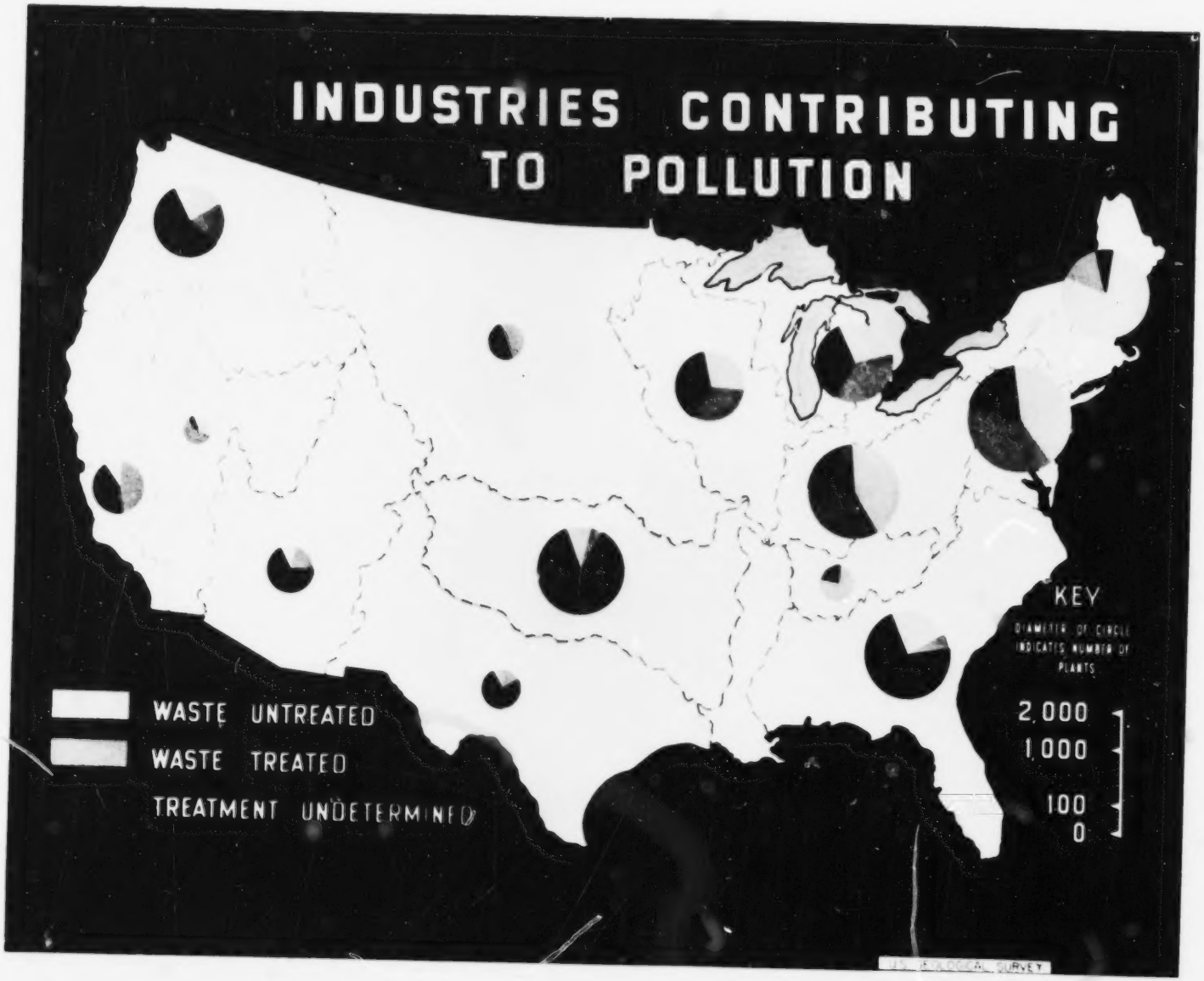

LEAVE ENOUGH
TO DILUTE WASTES
WASTE
GOOD
WASTE
BAD

Waste disposal is a beneficial and essential use of water. Although not usually classified as consumptive, a part of the total supply available must be allocated to waste disposal. Excessive withdrawals can deteriorate waste quality as much as excessive pollution.

A stream can dilute waste if the quantity of flow is good and the concentration of dissolved materials in the stream is low. Good water management encourages waste discharge during periods of high flow when the quantity of the dilutent is large and its chemical concentration is small.

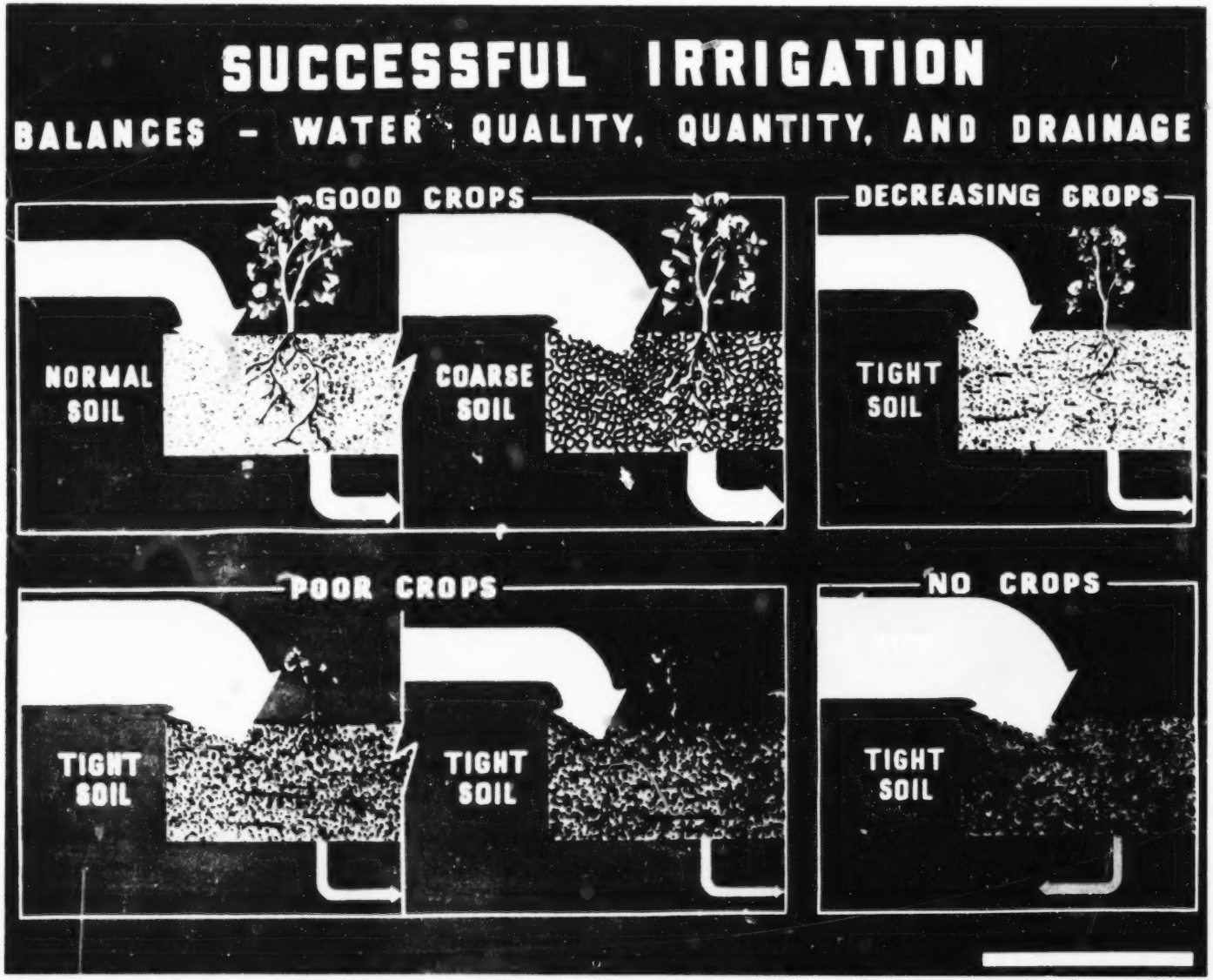

RECIRCULATION IN THE PETROLEUM REFINING INDUSTRY
BBL'S OF WATER PER BBL OF CRUDE OIL
NEW INTAKE
RECIRCULATED
NO RECIRCULATION
AVERAGE FOR INDUSTRY
EXTENSIVE RECIRCULATION

Water withdrawn from streams or wells per unit of product ranges widely. In some plants part of the water may be reused several times. For example, raw water withdrawn at a petroleum refinery may be only 5 percent of the amount in circulation in the plant. However, the water in circulation per gallon of crude oil processed is about the same whether or not water is recirculated. Recirculation is one means by which an industry can coexist with a meager water supply.


INDUSTRIES CONTRIBUTING TO POLLUTION
KEY
DIAMETER OF CIRCLE INDICATES NUMBER OF PLANTS
2,000
1,000
100
0
WASTE UNTREATED
WASTE TREATED
TREATMENT UNDETERMINED
U.S. GEOLOGICAL SURVEY

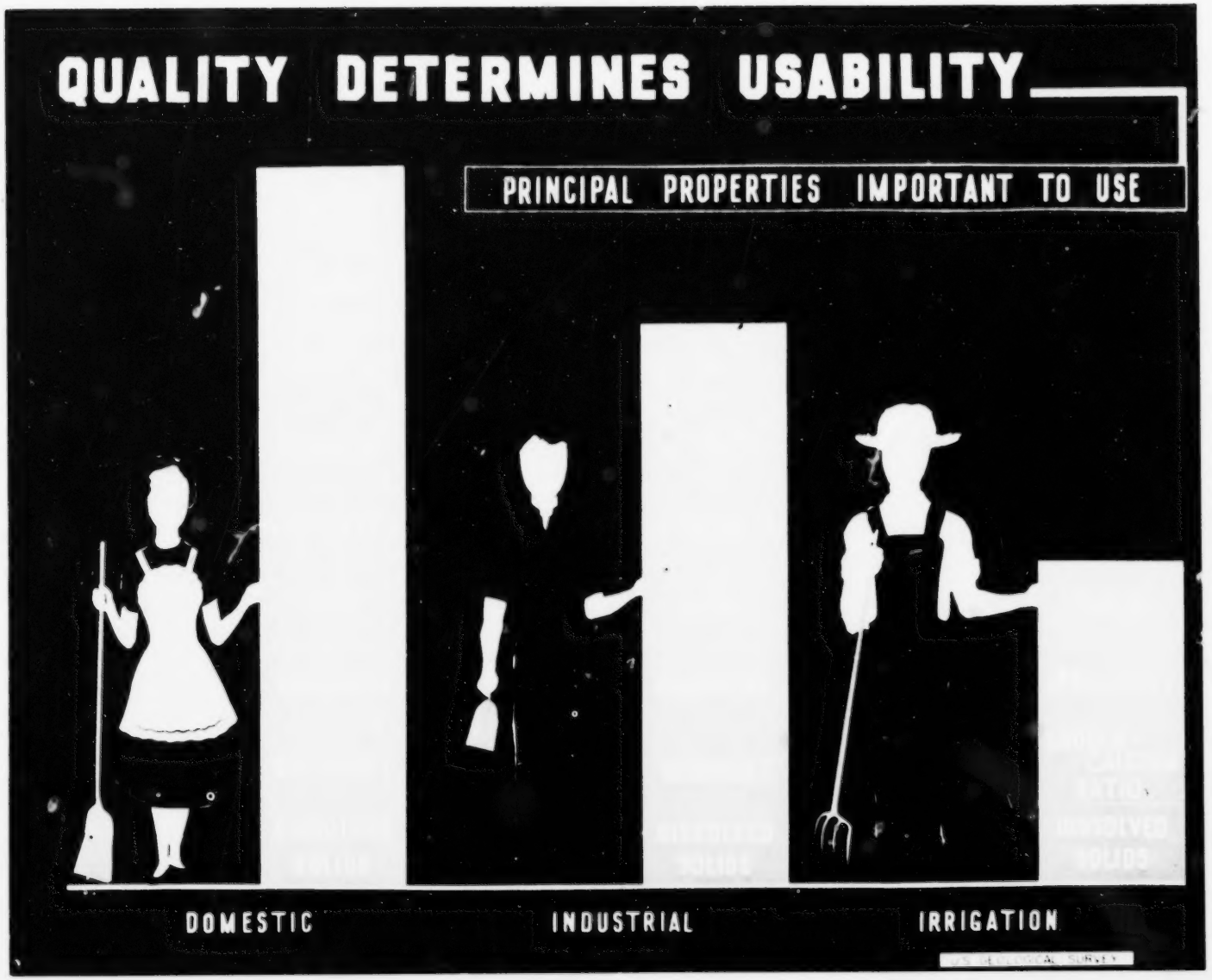
Pollution of industrial water is primarily a matter of adding waste products to the water supply. Wastes may be soluble and add to the chemical concentration, insoluble and add to the suspended concentration of the water, or grease and oily matter that floats on the surface. Many industrial wastes are toxic or noxious even in very small concentrations.

Many industries treat their wastes, but some do not. The principal problems of industrial waste treatment are technical and economic. Some wastes defy treatment under present technical knowledge and others cost so much to remove or destroy that treatment imposes a serious threat to the economic health of the industry.


SUCCESSFUL IRRIGATION
BALANCES - WATER QUALITY, QUANTITY, AND DRAINAGE
GOOD CROPS
NORMAL SOIL
COARSE SOIL
DECREASING CROPS
TIGHT SOIL
POOR CROPS
TIGHT SOIL
TIGHT SOIL
NO CROPS
TIGHT SOIL

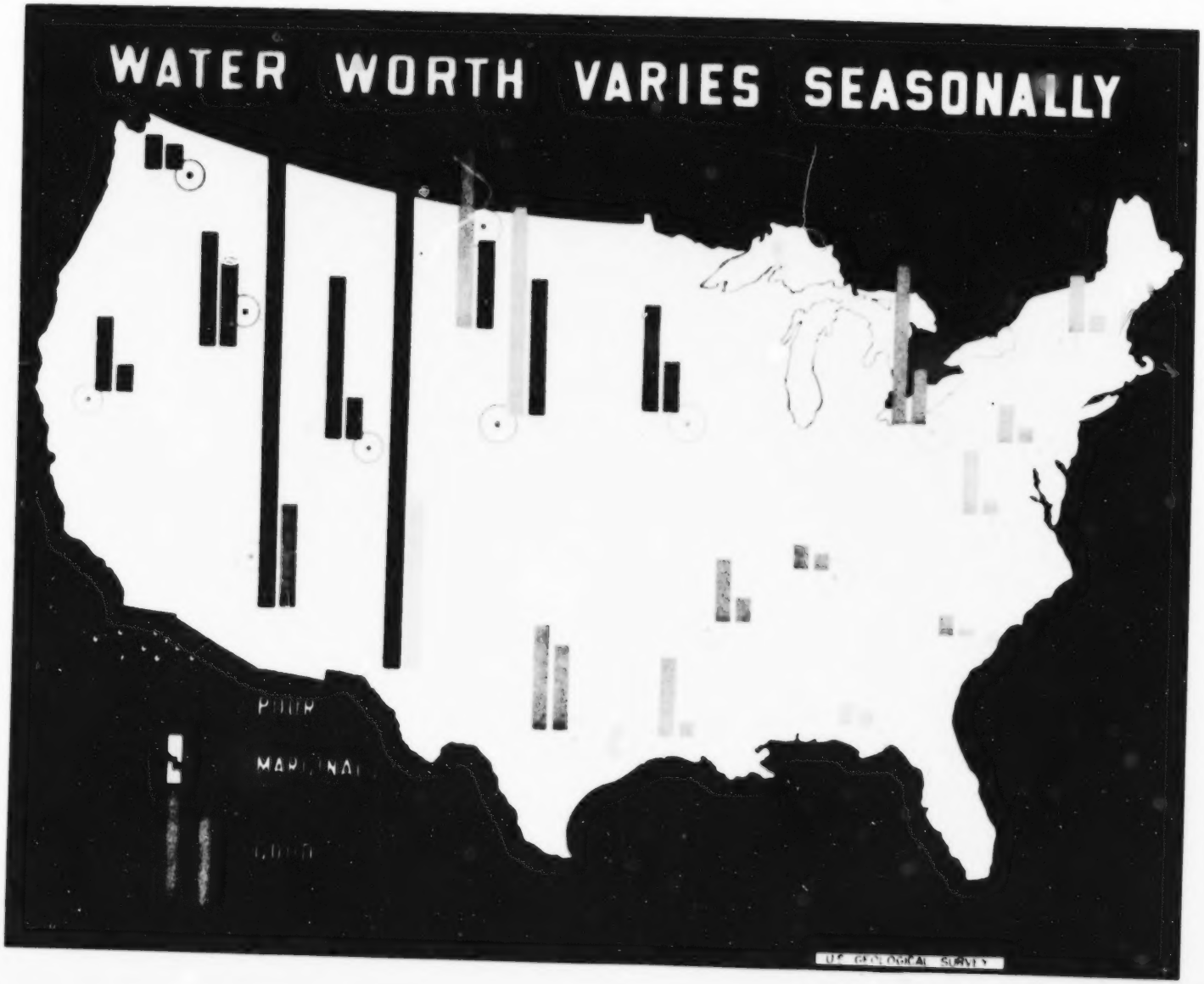
The concentration of dissolved salts in the soil solution in which plants grow influences the amount of water they will take up. In highly concentrated soil solutions plants will not take up water and will wither and die.

Irrigation always brings salts to the land. These salts will accumulate beyond the tolerable level unless drainage is adequate to flush them through the root zone. The greater the concentration of salts in the irrigation water the greater is the drainage required. On coarse, well-drained soil, relatively poor quality water can be used successfully if sufficient excess water is applied to flush the soil. Where the soil is too tight to drain sufficiently, serious problems arise that cannot be solved by over application of water.


QUALITY DETERMINES USABILITY
PRINCIPAL PROPERTIES IMPORTANT TO USE
DOMESTIC
INDUSTRIAL
IRRIGATION

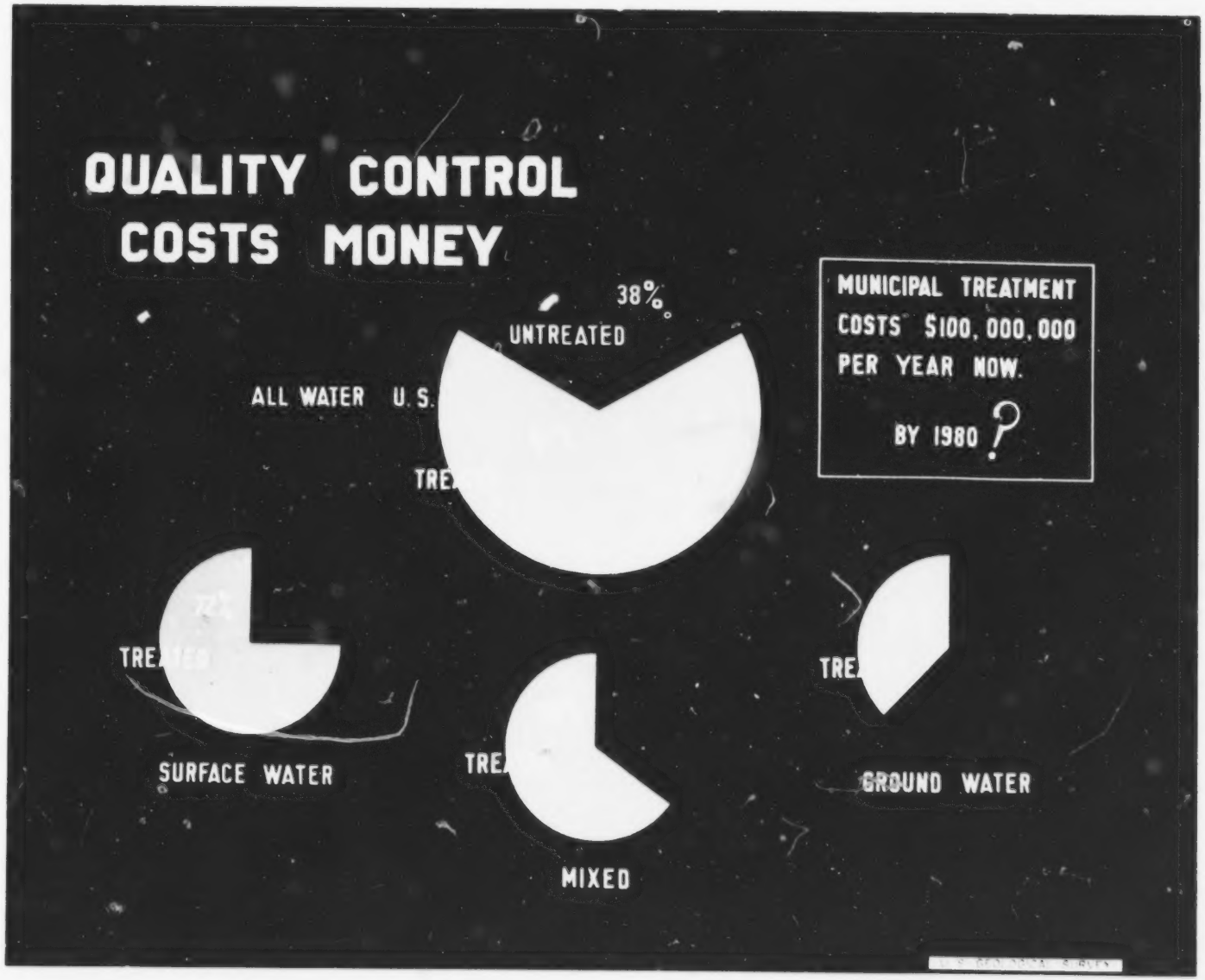
We could use sea water if the amount of gases, liquids, and solids dissolved in sea water didn't make it unfit for our use. Most present-day uses require water of better quality than sea water. Water unfit for drinking may be suitable for some industrial uses or irrigation. About 60 chemical and physical qualifications, excluding sanitary considerations, are pertinent to various uses—only the more common ones are included in the illustration.

Quality determines usability, consequently it sets a value on a given water supply. Some waters are suitable only for fighting fires, washing streets, or removing wastes; they have a low value. Others are of such excellent quality that they are in great demand. The increasing use of saline water and treated sewage for cooling is a good example of effective application of low-value water.


WATER WORTH VARIES SEASONALLY
PRIOR
MARGINAL
LOW
U.S. GEOLOGICAL SURVEY

One of the major natural phenomena plaguing development of the Nation's water resources is the seasonal and regional variations in quality. The seasonal spread between minimum and maximum concentrations of impurities in water is often as important as supply stability because additional construction and operation costs are incurred in treating a water of variable quality. Storage tends to stabilize quality by mixing the dilute and concentrated waters.

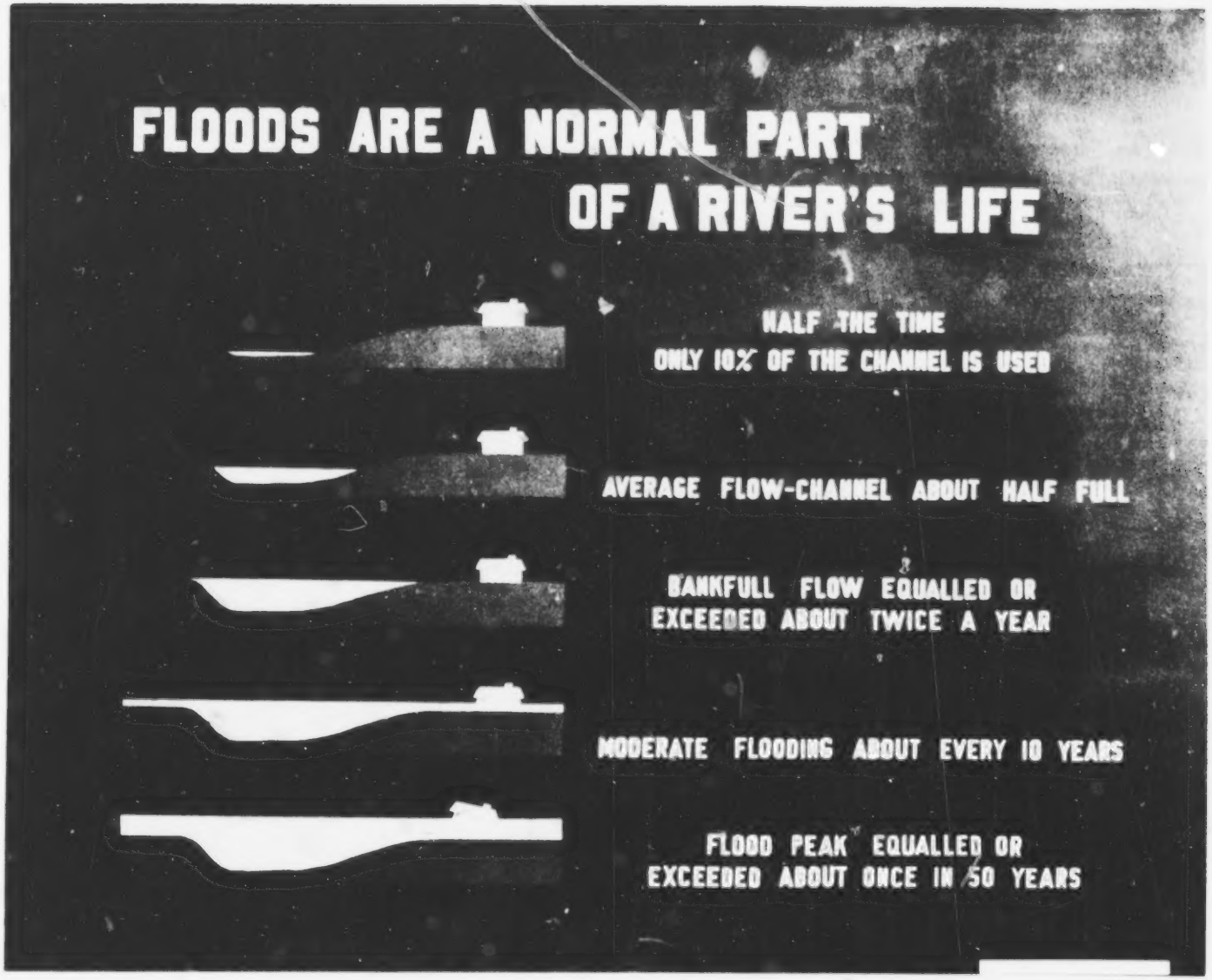
Regional variation is a natural problem with which one must live. In general, regions of poor quality coincide with regions of poor supply. Similarly, but not so closely correlated, are the seasonal variations in quality and quantity of water.


QUALITY CONTROL
COSTS MONEY
38%
UNTREATED
ALL WATER U.S.
TRE
MUNICIPAL TREATMENT
COSTS $100,000,000
PER YEAR NOW.
BY 1980 ?
72%
TRE
SURFACE WATER
TRE
MIXED
TRE
GROUND WATER

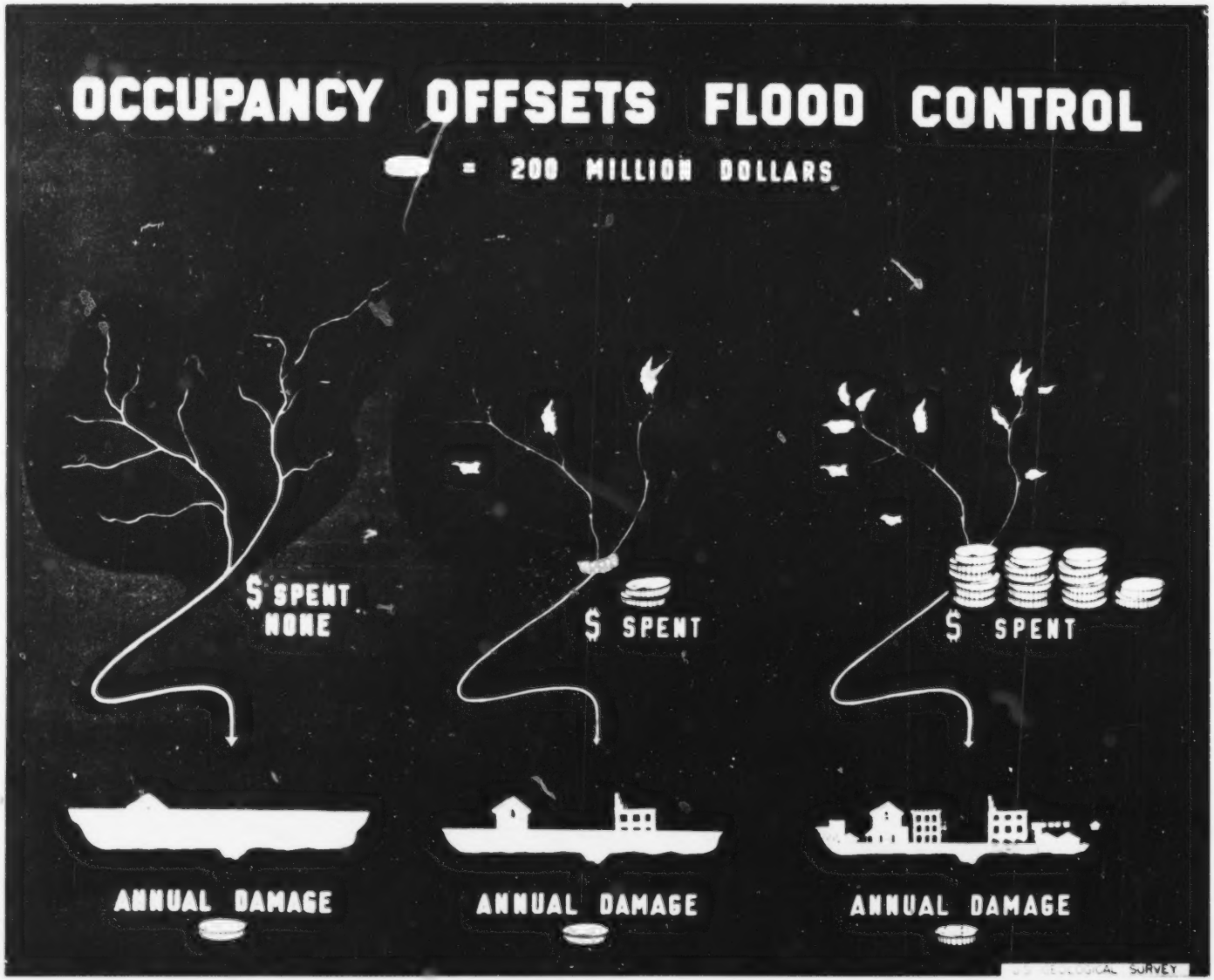
Water treatment refines an inferior raw water to meet our demands or desires for a high quality product. The data on the illustration do not include chlorination, which is used by most cities as a health measure.

Both the percentage of water treated for municipal use and the cost per unit volume will increase. Increasing demands for water will force us to draw on sources of poorer quality. Increasing pollution must be compensated for by more extensive treatment of public supplies. The public wants a better quality finished water, just as they want better homes and cars.

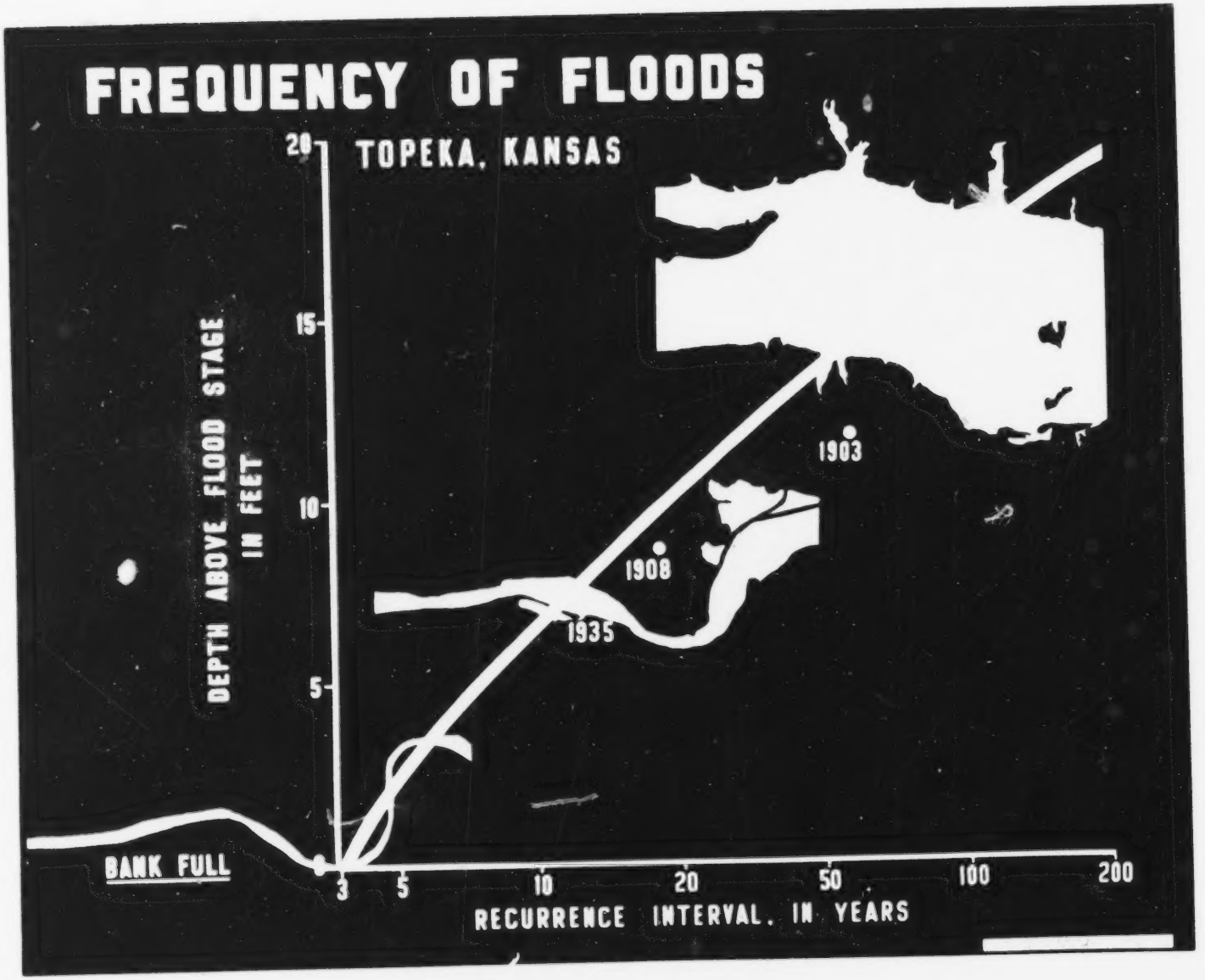
Most industries treat part of their intake. On the other hand, little irrigation water is treated now, but this practice definitely is in the picture for the future, either as direct treatment of the water or as soil additives.


FLOODS ARE A NORMAL PART
OF A RIVER'S LIFE
HALF THE TIME
ONLY 10% OF THE CHANNEL IS USED
AVERAGE FLOW-CHANNEL ABOUT HALF FULL
BANKFULL FLOW EQUALLED OR
EXCEEDED ABOUT TWICE A YEAR
MODERATE FLOODING ABOUT EVERY 10 YEARS
FLOOD PEAK EQUALLED OR
EXCEEDED ABOUT ONCE IN 50 YEARS

The flood plain is part of a river and is needed periodically to carry some of the flow. A river excavates a channel that can carry within its banks only the peak flows that occur on the average about twice a year. Higher peaks are carried by using the flood plain in addition to the regular channel. The frequency and depth of flow on the flood plain are characteristics that can be determined for a stream.


OCCUPANCY OFFSETS FLOOD CONTROL
= 200 MILLION DOLLARS
$ SPENT
NONE
$ SPENT
$ SPENT
ANNUAL DAMAGE
ANNUAL DAMAGE
ANNUAL DAMAGE

Floods are a natural aspect of rivers. Our expenditures for flood protection have not bought freedom from floods because we can't afford the cost of complete protection from the catastrophic flood. The advantages of flat terrain, proximity to water, and normally low land values attract industry to river bottoms and partial flood protection encourages further industrial development. Flood damages bring cries for flood relief which normally result in further flood protection works. Despite the increasing national annual expenditure for flood protection, the national annual flood damages remain the same because of the increase in occupancy of the partially protected flood plains. The damage that occurred during the 1951 flood on the Kansas River at Kansas City, Kans.-Mo., is an example of this.


FREQUENCY OF FLOODS
TOPEKA, KANSAS
DEPTH ABOVE FLOOD STAGE IN FEET
20
15
10
5
1903
1908
1935
BANK FULL
3
5
10
20
50
100
200
RECURRENCE INTERVAL, IN YEARS

Each stream has a characteristic time distribution of floods. Although we cannot forecast the size of floods which will occur next year, we can compute the probability that a flood of a given size may occur next year. The chart shows the flood probability, expressed as recurrence interval, for the Kansas River at Topeka, Kans. The stages at Topeka and their significance in terms of area flooded are shown for the 1935 and 1951 floods. The disastrous 1951 flood has a recurrence interval of 100 years.

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